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Noninvasive Biomagnetic Sensing of Biological Currents

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Biological currents flowing in the body produce magnetic fields that could be detected and mapped with cryogenic SQUID (Superconducting Quantum Interference Device) biomagnetometers. These are noninvasive noncontact measurements. By solving the biomagnetic inverse problem the current distribution in the tissue could reconstructed. These techniques can also be applied for reconstruction of current distributions in isolated tissue samples in a conducting medium. A brief review of the reconstruction techniques and examples are given here.

Magnetic field produced by a current distribution is given by the Biot-Savart law. In matrix form it could be written as, $[B] = [R]\,[J]$, where B is the magnetic field, R is the distance between the source and field point where the magnetic field is sampled, and J is a planar current distribution consisting of several dipoles. Often the number of magnetic field measurements is less than the number of unknown dipoles in a current distribution, thus the inverse problem becomes under-determined. The current distribution could be solved by the generalized minimum norm solution techniques. It is given as: $[J] = [R]^T \{[R][R]^T\}^{-1}[B]$. This provides an optimum estimate of the current distributions. In our reconstructions we found that there is always noise present based on the number of samples, and the size of sample and reconstruction space. A general shape of the current distribution is recognizable, but the reconstructed images are blurred. Thus image restoration becomes necessary. Making an assumption that all the current distribution are composed of line-like sources, we have used alternating projections techniques to restore the images. The procedure is to use the minimum norm solution as the initial guess and project it on a line-like space to obtain the next best estimate of the image. The iterative procedure is continued till the difference between two successive projections has reached the lowest limit.

Theses procedures were applied to the reconstructions of parallel conductors, circular current distribution, a complex pattern of current distribution in the shape of letters UWBC, dipoles in the brain, and an excitation pathway of the heart. In all the examples considered we were able to reconstruct the original shape of the current distribution.